

## Submission Questions:

18.

a) What operating system (including revision) did you use for your code development?

Ans: Windows 11

b) What compiler (including revision) did you use?

Ans: SDCC

c) What exactly (include name/revision if appropriate) did you use to build your code (what IDE, make/makefile, or command line)?

Ans: STM32CubeIDE 1.13.2 and CodeBlocks:SDCC

d) Did you install and use any other software tools to complete your lab assignment?

Ans No.

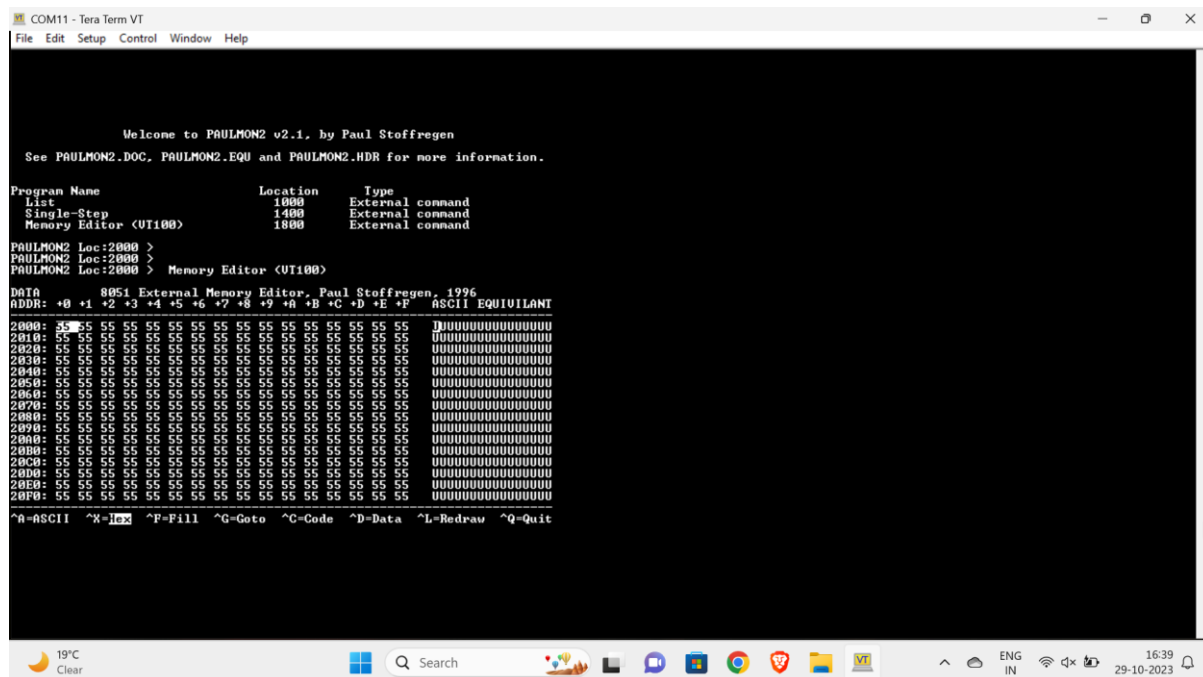
e) Did you experience any problems with any of the software tools? If so, describe the problems.

Ans: No

## Pictures/Screenshots:

1. Part 1: Terminal output after filling the data segment with a "U" character (55).

Data segment:



```
COM11 - Tera Term VT
File Edit Setup Control Window Help

Welcome to PAULMON2 v2.1, by Paul Stoffregen
See PAULMON2.DOC, PAULMON2.EQU and PAULMON2.HDR for more information.

Program Name      Location      Type
List              1000          External command
Single-Step       1400          External command
Memory Editor <UT100> 1800          External command

PAULMON2 Loc:2000 >
PAULMON2 Loc:2000 >
PAULMON2 Loc:2000 > Memory Editor <UT100>

DATA      8051 External Memory Editor, Paul Stoffregen, 1996
ADDR: +0 +1 +2 +3 +4 +5 +6 +7 +8 +9 +A +B +C +D +E +F ASCII EQUIVILANT
2000: 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 UUUUUUUUUUUUUUUUUUU
2010: 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 UUUUUUUUUUUUUUUUUUU
2020: 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 UUUUUUUUUUUUUUUUUUU
2030: 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 UUUUUUUUUUUUUUUUUUU
2040: 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 UUUUUUUUUUUUUUUUUUU
2050: 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 UUUUUUUUUUUUUUUUUUU
2060: 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 UUUUUUUUUUUUUUUUUUU
2070: 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 UUUUUUUUUUUUUUUUUUU
2080: 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 UUUUUUUUUUUUUUUUUUU
2090: 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 UUUUUUUUUUUUUUUUUUU
20A0: 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 UUUUUUUUUUUUUUUUUUU
20B0: 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 UUUUUUUUUUUUUUUUUUU
20C0: 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 UUUUUUUUUUUUUUUUUUU
20D0: 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 UUUUUUUUUUUUUUUUUUU
20E0: 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 UUUUUUUUUUUUUUUUUUU
20F0: 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 55 UUUUUUUUUUUUUUUUUUU
^A=ASCII ^X=Hex ^F=Fill ^G=Goto ^C=Code ^D=Data ^L=Redraw ^Q=Quit
```

Downloading a file using “D” command in PAULMON2.

```
COM11 - Tera Term VT
File Edit Setup Control Window Help

Welcome to PAULMON2 v2.1, by Paul Stoffregen
See PAULMON2.DOC, PAULMON2.EQU and PAULMON2.HDR for more information.

Program Name      Location    Type
List              1000      External command
Single-Step       1400      External command
Memory Editor <UI100> 1800      External command

PAULMON2 Loc:2000 > Download
Begin ascii transfer of Intel hex file, or ESC to abort
.....
Download completed
Summary:
648 lines received
10190 bytes received
10190 bytes written
No errors detected

PAULMON2 Loc:2000 > █
```

## 2.Part2: Creating buffers.

Creating buffers 0 and 1 with equal size with the input number which is between 32 and 4800 both inclusive.

The input number must be divisible by 16.

```
COM11 - Tera Term VT
File Edit Setup Control Window Help

Welcome to PAULMON2 v2.1, by Paul Stoffregen
See PAULMON2.DOC, PAULMON2.EQU and PAULMON2.HDR for more information.

Program Name      Location    Type
List              1000      External command
Single-Step       1400      External command
Memory Editor <UI100> 1800      External command

PAULMON2 Loc:2000 > Jump to memory location
Jump to memory location <2000>, or ESC to quit: 2000
running program:

WELCOME
Enter a number between 32 and 4800 which is divisible by 16
640
entered input:640
input number:640
valid input
Memory allocated successfully for buffer 0 and buffer 1
buffer 0 starts at address: 0x3
buffer 1 starts at address: 0x285

OPTIONS
You can enter storage characters from 'A' to 'Z' to store in buffer 0
Press + to create a new buffer of size between 20 and 400 bytes
Press - to delete a buffer.
Press ? to generate a heap report.
Press = to display current contents of buffer 0.
Press 0 to free all buffers and start program again.

enter the input
```

Terminal output when the input is a storage character.

```
COM11 - Tera Term VT
File Edit Setup Control Window Help
Press = to display current contents of buffer 0.
Press 0 to free all buffers and start program again.
enter the input
p
OPTIONS
You can enter storage characters from 'A' to 'Z' to store in buffer 0
Press + to create a new buffer of size between 20 and 400 bytes
Press - to delete a buffer.
Press ? to generate a heap report.
Press = to display current contents of buffer 0.
Press 0 to free all buffers and start program again.
enter the input
a
OPTIONS
You can enter storage characters from 'A' to 'Z' to store in buffer 0
Press + to create a new buffer of size between 20 and 400 bytes
Press - to delete a buffer.
Press ? to generate a heap report.
Press = to display current contents of buffer 0.
Press 0 to free all buffers and start program again.
enter the input
l
OPTIONS
You can enter storage characters from 'A' to 'Z' to store in buffer 0
Press + to create a new buffer of size between 20 and 400 bytes
Press - to delete a buffer.
Press ? to generate a heap report.
Press = to display current contents of buffer 0.
Press 0 to free all buffers and start program again.
enter the input
L
OPTIONS
You can enter storage characters from 'A' to 'Z' to store in buffer 0
Press + to create a new buffer of size between 20 and 400 bytes
Press - to delete a buffer.
Press ? to generate a heap report.
Press = to display current contents of buffer 0.
Press 0 to free all buffers and start program again.
enter the input
y
OPTIONS
You can enter storage characters from 'A' to 'Z' to store in buffer 0
Press + to create a new buffer of size between 20 and 400 bytes
Press - to delete a buffer.
Press ? to generate a heap report.
Press = to display current contents of buffer 0.
Press 0 to free all buffers and start program again.
```

Terminal output when the input is "+", creating new buffers whose size must be between 20 and 400.

```
COM11 - Tera Term VT
File Edit Setup Control Window Help
Press = to free all buffers and start program again.
enter the input
+
enter buffer size between 20 AND 400 for the new buffer
200
entered input:200
memory allocation successful for buffer 2
OPTIONS
You can enter storage characters from 'A' to 'Z' to store in buffer 0
Press + to create a new buffer of size between 20 and 400 bytes
Press - to delete a buffer.
Press ? to generate a heap report.
Press = to display current contents of buffer 0.
Press 0 to free all buffers and start program again.
enter the input
+
enter buffer size between 20 AND 400 for the new buffer
150
entered input:150
memory allocation successful for buffer 3
OPTIONS
You can enter storage characters from 'A' to 'Z' to store in buffer 0
Press + to create a new buffer of size between 20 and 400 bytes
Press - to delete a buffer.
Press ? to generate a heap report.
Press = to display current contents of buffer 0.
Press 0 to free all buffers and start program again.
enter the input
-
enter the buffer number to be deleted
2
entered input:2
Freed buffer_2
OPTIONS
You can enter storage characters from 'A' to 'Z' to store in buffer 0
Press + to create a new buffer of size between 20 and 400 bytes
Press - to delete a buffer.
Press ? to generate a heap report.
Press = to display current contents of buffer 0.
Press 0 to free all buffers and start program again.
enter the input
```

Terminal output depicting the Heap Report when input is “?”

```
COM11 - Tera Term VT
File Edit Setup Control Window Help
Press ? to generate a heap report.
Press = to display current contents of buffer 0.
Press 0 to free all buffers and start program again.
enter the input
?
HEAP REPORT
Buffer 0 starts at = 0x3
Buffer 0 ends at =x283
Buffer 0 size =640
number of storage characters in buffer 0=18
number of free spaces in buffer 0=622

Buffer 1 starts at = 0x285
Buffer 1 ends at =x505
Buffer 1 size =640
number of storage characters in buffer 1=0
number of free spaces in buffer 1=640

Buffer 3 starts at = 0x5D1
Buffer 3 ends at =x667
Buffer 3 size =150
number of storage characters in buffer 3=0
number of free spaces in buffer 3=150
characters in buffer 0
stored chars=18
total characters entered=23
SHRUTHITHALLAPALLY
heap report is done
OPTIONS
```

Terminal output depicting the Heap Report when input is “=”

```
COM11 - Tera Term VT
File Edit Setup Control Window Help
Press 0 to free all buffers and start program again.
enter the input
=
enter the buffer number to be deleted
2
entered input:2
Freed buffer_2
OPTIONS
You can enter storage characters from 'A' to 'Z' to store in buffer 0
Press + to create a new buffer of size between 20 and 400 bytes
Press - to delete a buffer.
Press ? to generate a heap report.
Press = to display current contents of buffer 0.
Press 0 to free all buffers and start program again.
enter the input
=
contents of buffer 0
storage character -- its hexadecimal representation
S--53
H--48
R--52
U--55
T--54
H--48
I--49
I--54
H--48
A--41
L--4C
L--4C
A--41
R--50
A--41
L--4C
L--4C
Y--59
OPTIONS
You can enter storage characters from 'A' to 'Z' to store in buffer 0
Press + to create a new buffer of size between 20 and 400 bytes
Press - to delete a buffer.
Press ? to generate a heap report.
Press = to display current contents of buffer 0.
Press 0 to free all buffers and start program again.
enter the input
```

Terminal output 2 depicting the Heap Report when input is “@”

```
COM11 - Tera Term VT
File Edit Setup Control Window Help
number of storage characters in buffer 1=0
number of free spaces in buffer 1=640

Buffer 3 starts at = 0x5D1
Buffer 3 ends at ~x667
Buffer 3 size ~150
number of storage characters in buffer 3=0
number of free spaces in buffer 3=150
characters in buffer 0
stored chars=18
total characters entered=23
SHRUTHITHALLAPALLY
heap report is done

OPTIONS
You can enter storage characters from 'A' to 'Z' to store in buffer 0
Press + to create a new buffer of size between 20 and 400 bytes
Press - to delete a buffer.
Press ? to generate a heap report.
Press = to display current contents of buffer 0.
Press 0 to free all buffers and start program again.

enter the input
@
buffer 0 is freed
buffer 1 is freed
buffer 2 is freed
buffer 2 is freed
all buffers are freed. Please start from the beginning

WELCOME
Enter a number between 32 and 4800 which is divisible by 16
entered input:0
input number:0
invalid input. Try again
```

Terminal output 2 when invalid inputs are given.

```
COM11 - Tera Term VT
File Edit Setup Control Window Help

entered input:0
input number:0
invalid input. Try again
20
entered input:20
input number:20
invalid input. Try again
2400
entered input:2400
input number:2400
valid input
buffer 1 malloc failed. free all malloc

WELCOME
Enter a number between 32 and 4800 which is divisible by 16
640
entered input:640
input number:640
valid input
Memory allocated successfully for buffer 0 and buffer 1
buffer 0 starts at address: 0x3
buffer 1 starts at address: 0x285

OPTIONS
You can enter storage characters from 'A' to 'Z' to store in buffer 0
Press + to create a new buffer of size between 20 and 400 bytes
Press - to delete a buffer.
Press ? to generate a heap report.
Press = to display current contents of buffer 0.
Press 0 to free all buffers and start program again.

enter the input
+
enter buffer size between 20 AND 400 for the new buffer
500
entered input:500

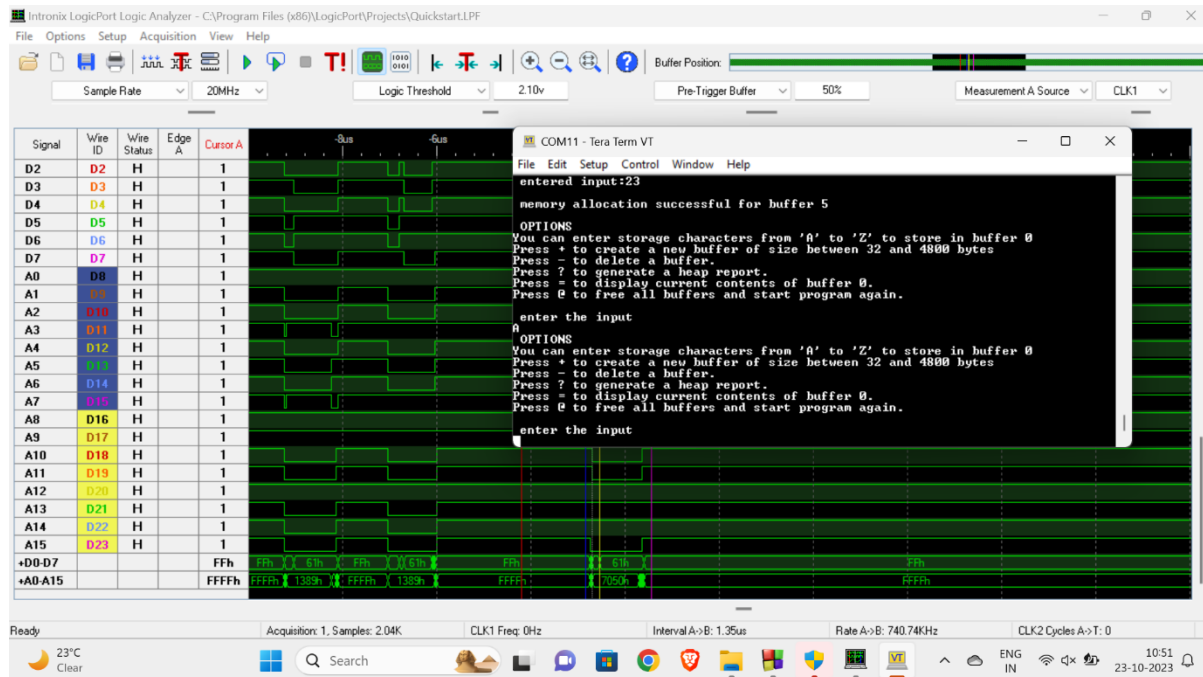
Invalid buffer size.To try again press '+'
memory allocation failed for buffer 2

OPTIONS
You can enter storage characters from 'A' to 'Z' to store in buffer 0
Press + to create a new buffer of size between 20 and 400 bytes
Press - to delete a buffer.
Press ? to generate a heap report.
Press = to display current contents of buffer 0.
Press 0 to free all buffers and start program again.

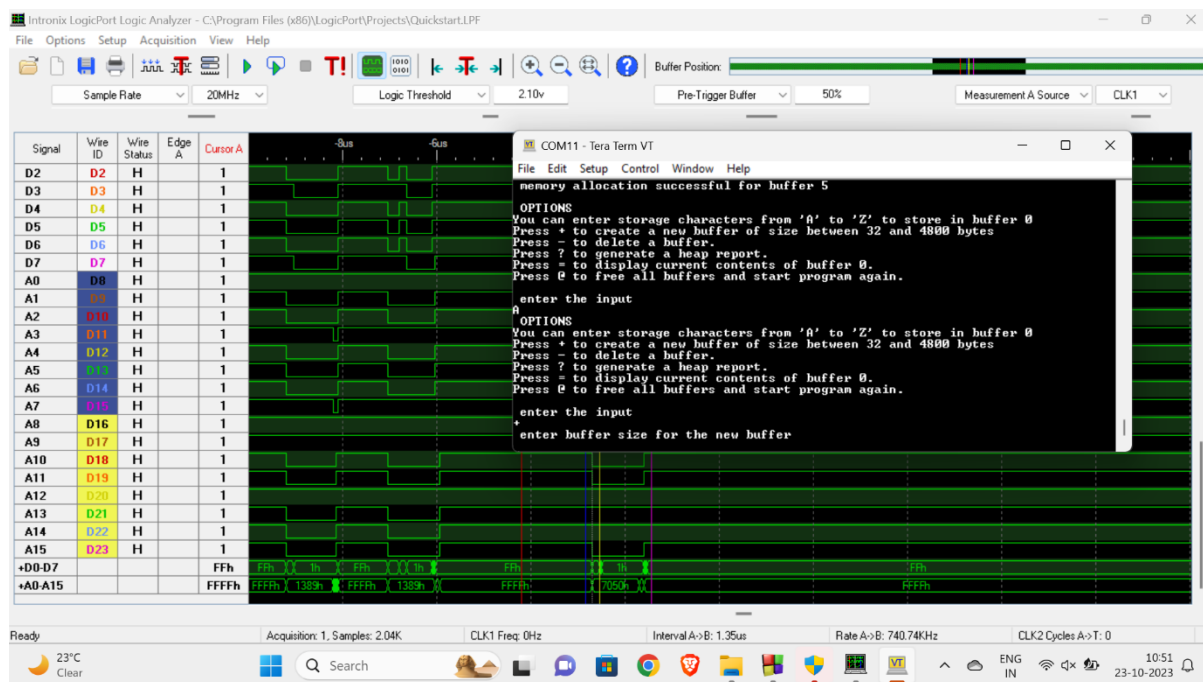
enter the input
```

### 3. Logic analyzer pictures of Virtual Debug port.

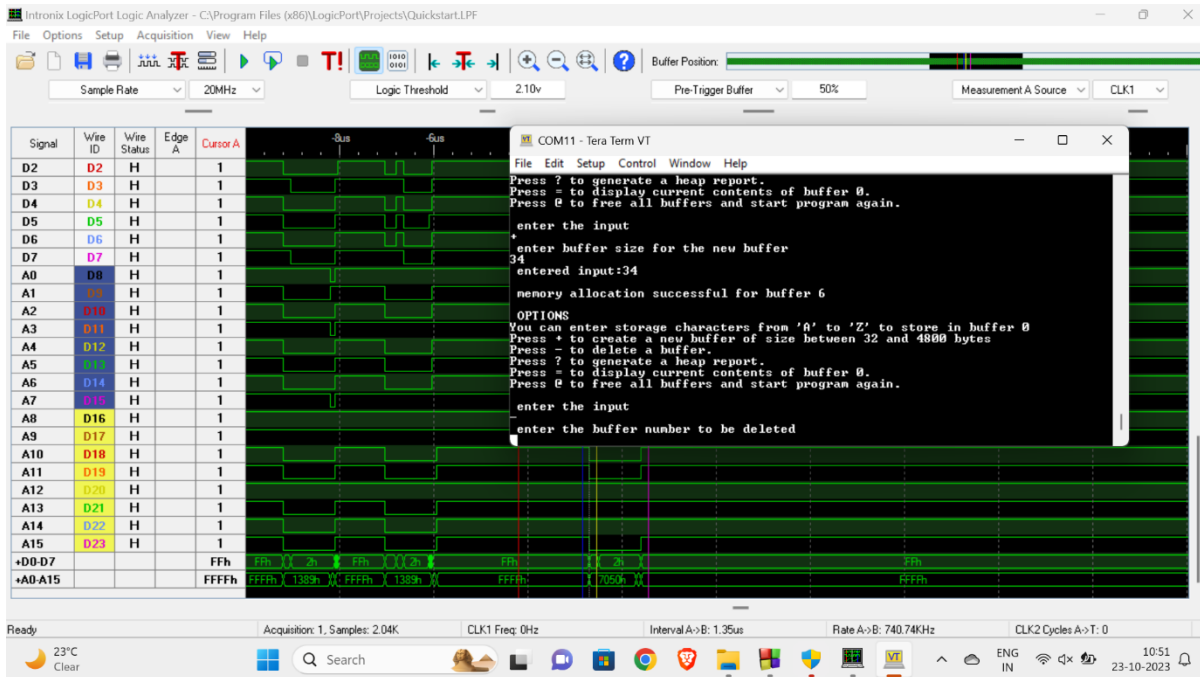
For a storage Character in Buffer 0:



For a "+" input:



For a “-” input :



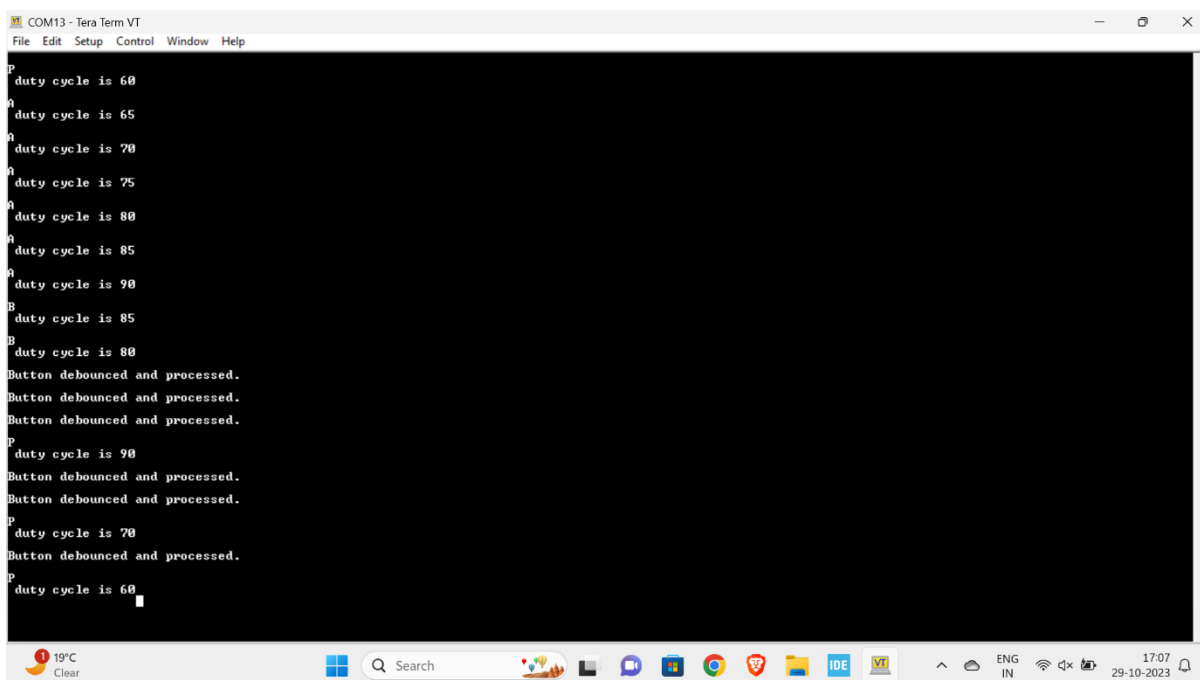
#### 4. Part3: Terminal Pictures

For the required part, one GPIO pin is used to generate the PWM signal with a default 60% duty cycle. The duty cycle increases by 5% every time A is given as input.

The duty cycle decreases by 5% every time A is given as input.

The duty cycle increases/decreases by 10% every time the button is pressed.

When P is given as input, the current duty cycle is displayed.

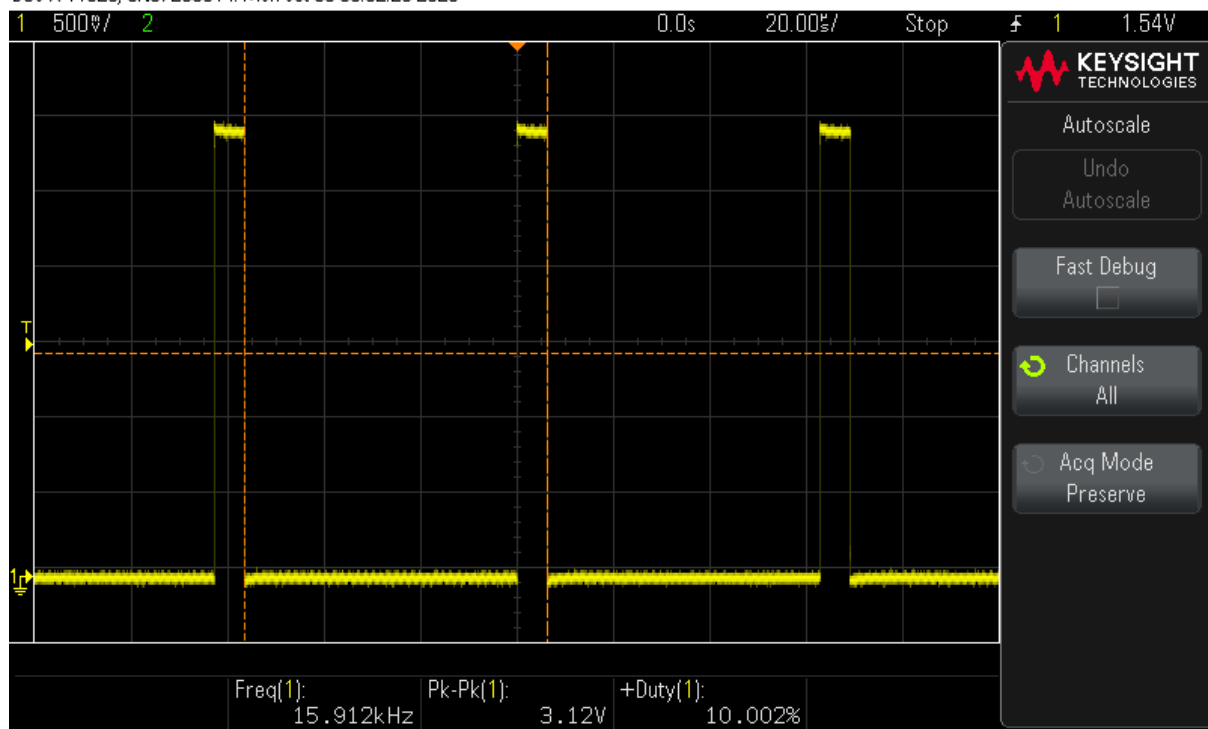


```
COM13 - Tera Term VT
File Edit Setup Control Window Help
duty cycle is 85
B
duty cycle is 80
Button debounced and processed.
Button debounced and processed.
Button debounced and processed.
P
duty cycle is 90
Button debounced and processed.
Button debounced and processed.
P
duty cycle is 70
Button debounced and processed.
P
duty cycle is 60
Button debounced and processed.
Button debounced and processed.
Button debounced and processed.
Button debounced and processed.
Button debounced and processed.
P
duty cycle is 0
B
duty cycle is 0
B
duty cycle is 0
Button debounced and processed.
P
duty cycle is 10
```

Oscilloscope pictures for different duty cycles varied by giving “A,” “B” and button.

Duty cycle=10%

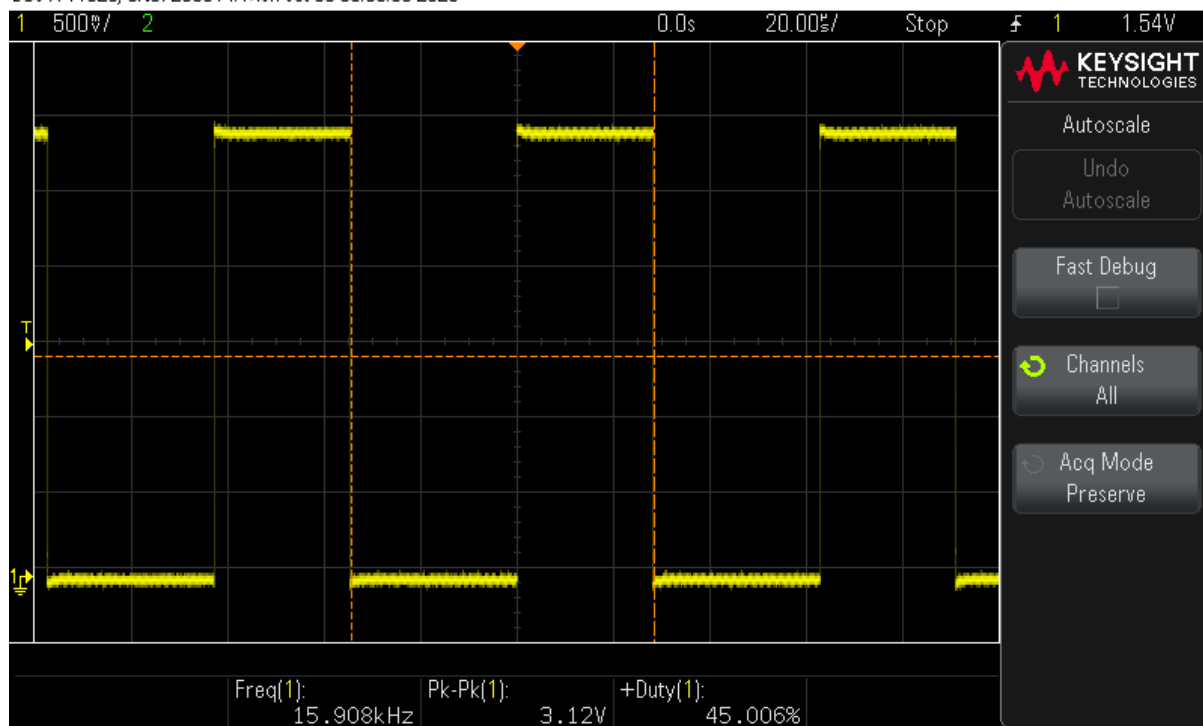
DSO-X 1102G, CN57266514: Mon Oct 30 06:52:29 2023





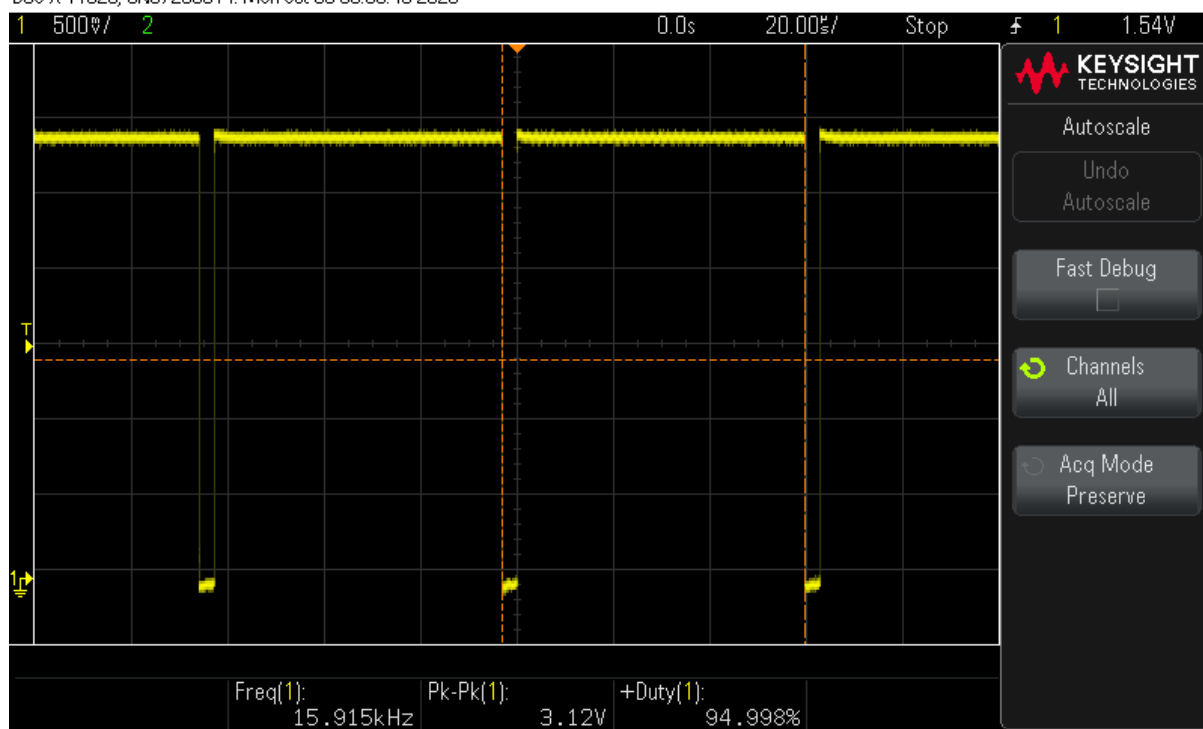
Duty cycle= 45%

DSO-X 11026, CN57266514: Mon Oct 30 06:53:08 2023



Duty cycle=95%

DSO-X 11026, CN57266514: Mon Oct 30 06:53:45 2023



## 5. Terminal Pictures:

For supplemental elements, demonstrating the PCA modes.

-Pulse Width Modulation

-High-Speed output

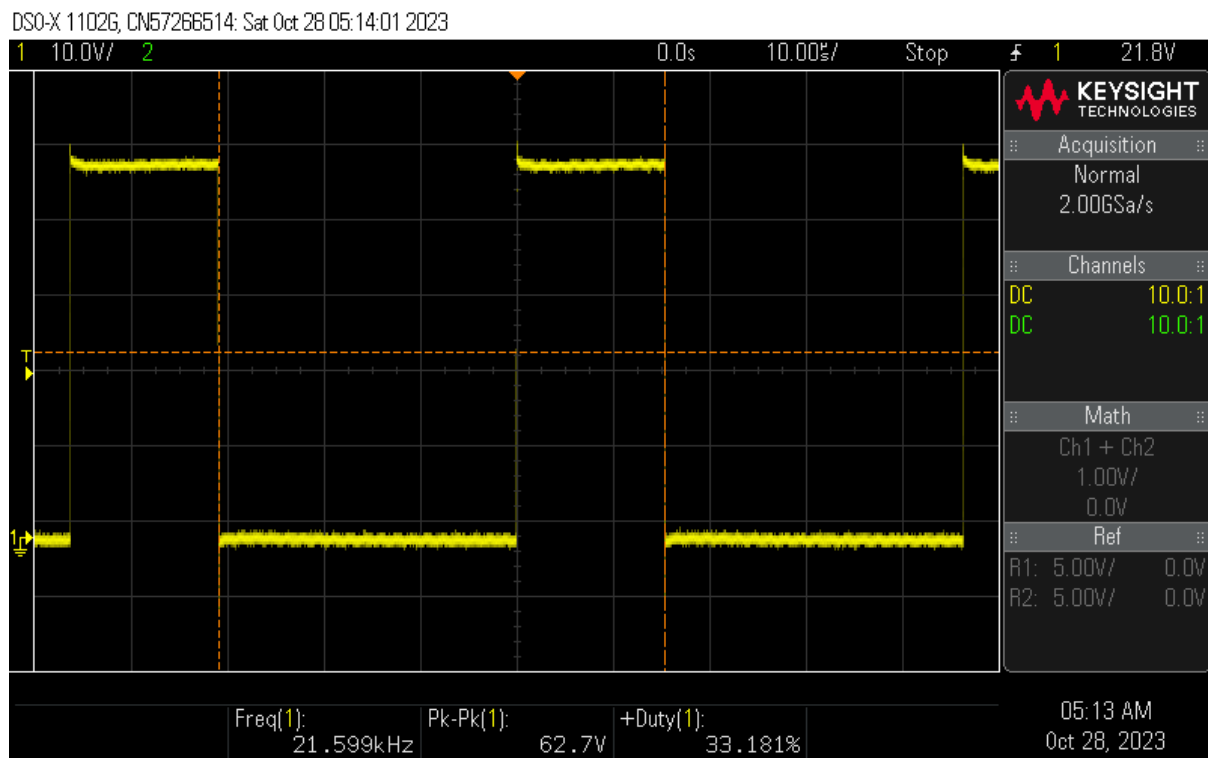
```
COM11 - Tera Term VT
File Edit Setup Control Window Help
PAULMON2 Loc:2000 >
Jump to memory location
Jump to memory location <2000>, or ESC to quit: 3000
running program:

=====MENU=====
1. Run PUM
2. Stop PUM
3. High speed output mode
4. min CKRL frequency
5. max CKRL frequency
6.menu
Enter a number from menu or press 6 to see menu again
1 entered input:1
PUM ON
Enter a number from menu or press 6 to see menu again
2 entered input:2
PUM OFF
Enter a number from menu or press 6 to see menu again
3 entered input:3
High-Speed mode
Enter a number from menu or press 6 to see menu again
5 entered input:5
Maximum Frequency
Enter a number from menu or press 6 to see menu again
6 entered input:6
=====MENU=====
1. Run PUM
```

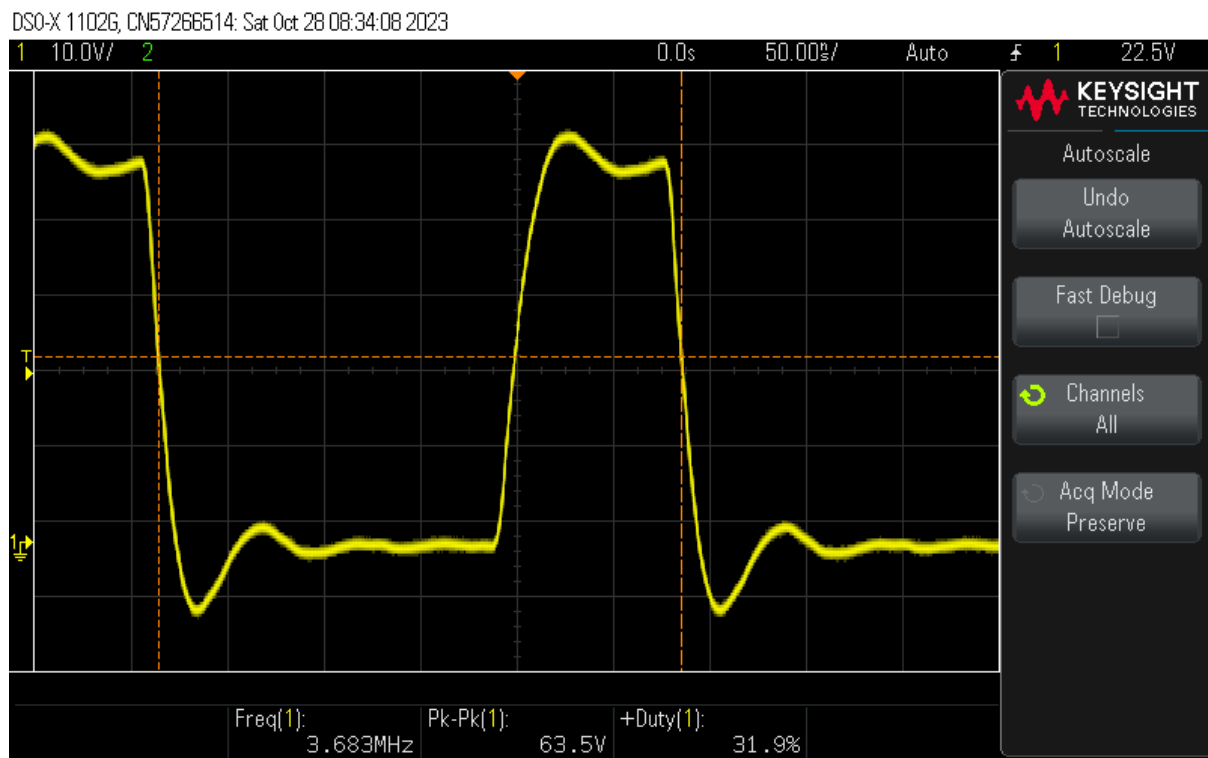
```
COM11 - Tera Term VT
File Edit Setup Control Window Help
entered input:2
PUM OFF
Enter a number from menu or press 6 to see menu again
3 entered input:3
High-Speed mode
Enter a number from menu or press 6 to see menu again
5 entered input:5
Maximum Frequency
Enter a number from menu or press 6 to see menu again
6 entered input:6
=====MENU=====
1. Run PUM
2. Stop PUM
3. High speed output mode
4. min CKRL frequency
5. max CKRL frequency
6.menu
Enter a number from menu or press 6 to see menu again
4 entered input:4
Minimum Frequency
```

Oscilloscope pictures:

For the supplementary part, one GPIO pin is configured for PWM duty cycle of 33%.

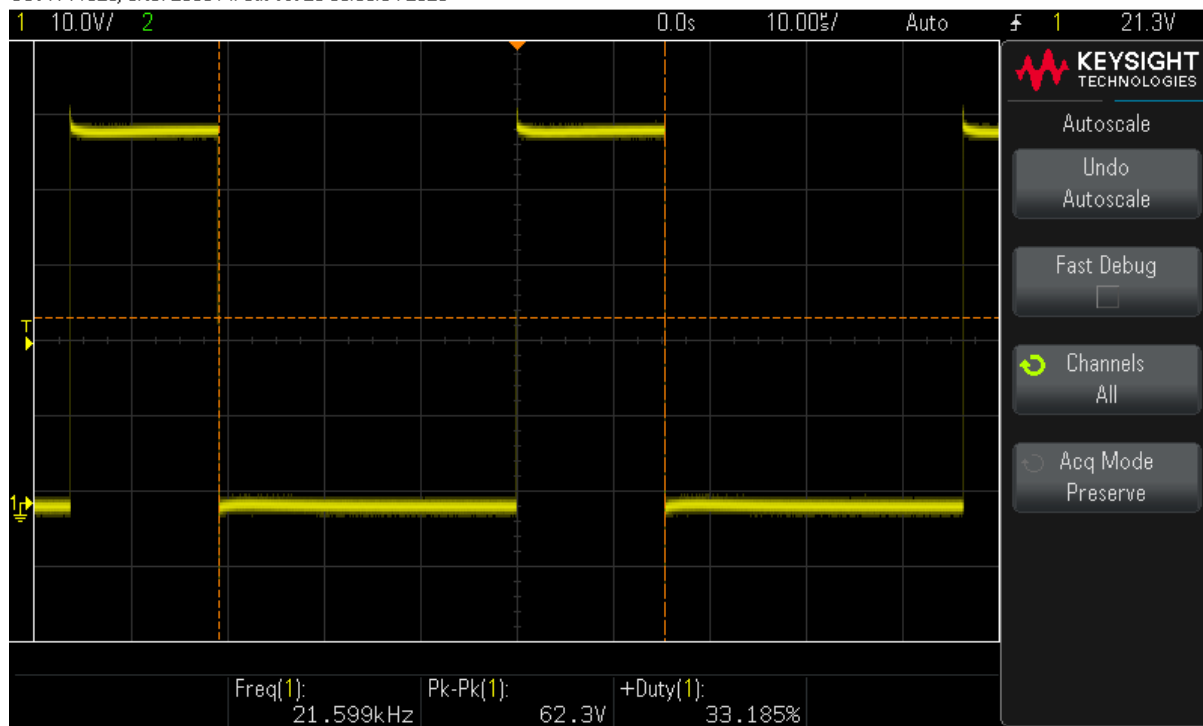


For the supplementary part, one pin is set for High-Speed Output.



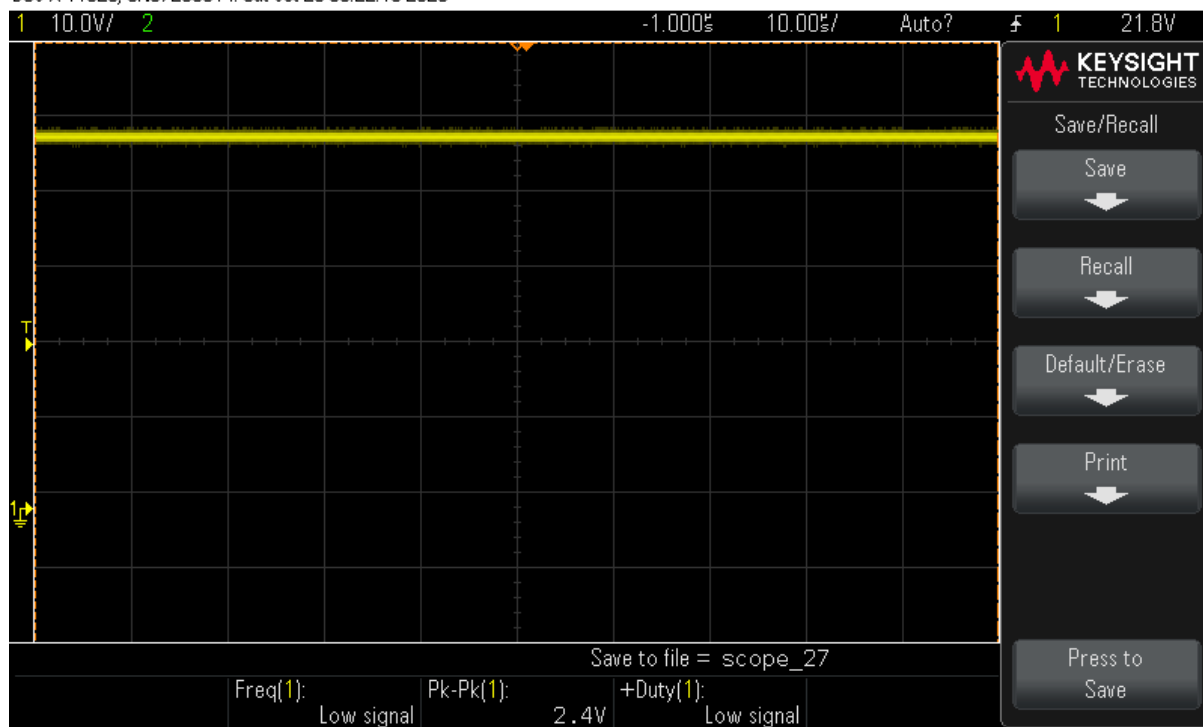
For the supplementary part, when PWM is ON for one pin.

DSO-X 1102G, CN57266514: Sat Oct 28 08:33:34 2023



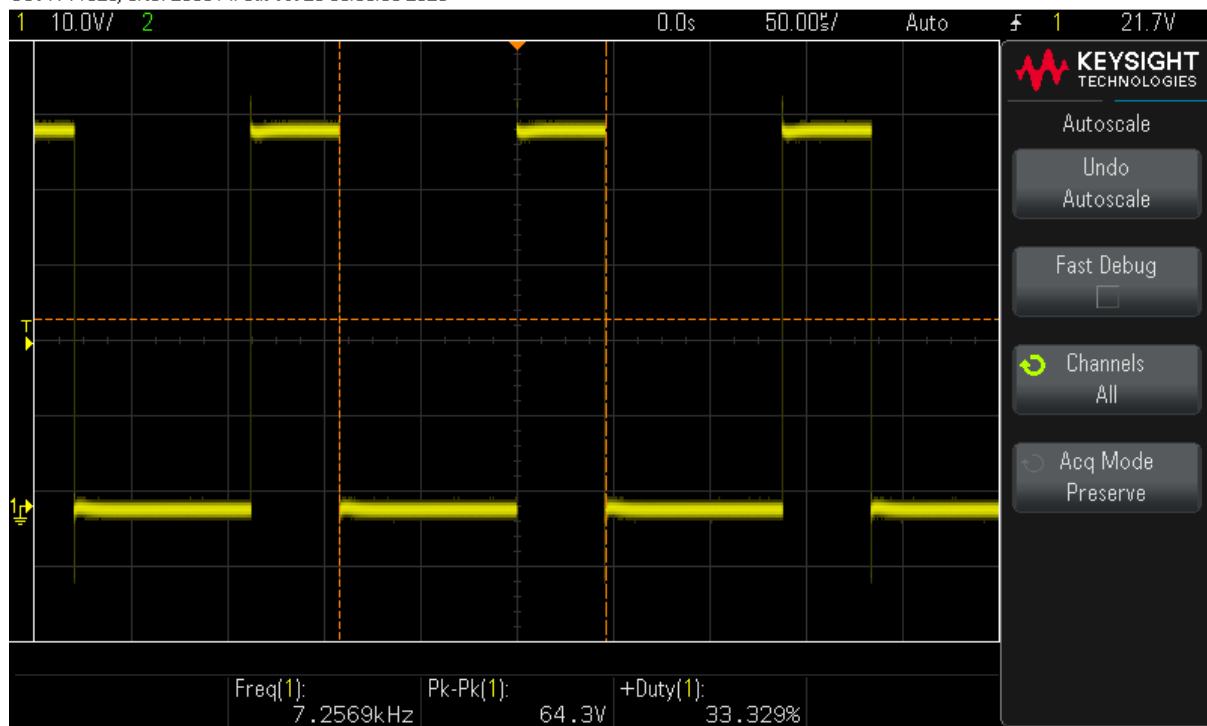
For the supplementary part, when PWM is OFF for one pin.

DSO-X 1102G, CN57266514: Sat Oct 28 05:22:13 2023



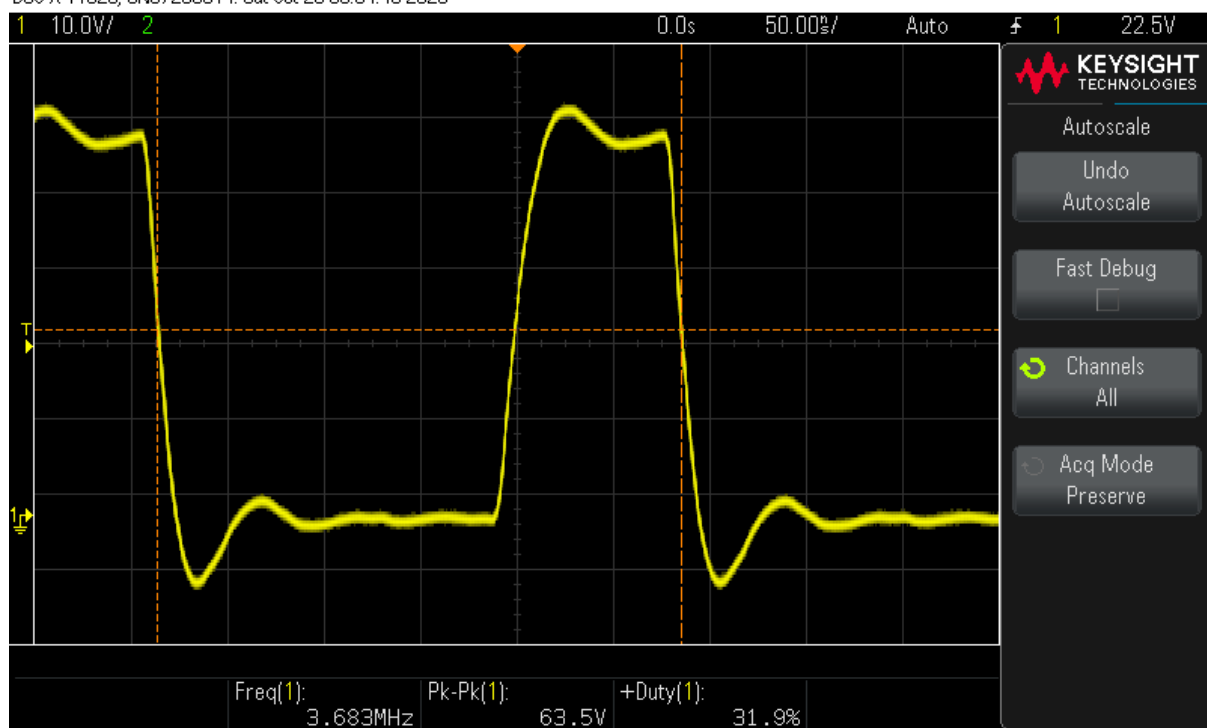
the supplementary part, output at ALE when one pin is set to the minimum peripheral clock frequency supported by the CKRL register.

DSO-X 1102G, CN57266514: Sat Oct 28 08:35:55 2023



For the supplementary part, output at ALE when one pin is set to the maximum peripheral clock frequency supported by the CKRL register.

DSO-X 1102G, CN57266514: Sat Oct 28 08:34:43 2023



For the optional challenges part, where the heap is created with 5600 bytes. Heap report after creating a buffer of 100 bytes.

```
COM11 - Tera Term VT
File Edit Setup Control Window Help
HEAP REPORT
Buffer 0 starts at = 0x3
Buffer 0 ends at ~x963
Buffer 0 size ~2400
number of storage characters in buffer 0=0
number of free spaces in buffer 0~2400

Buffer 1 starts at = 0x965
Buffer 1 ends at ~x12C5
Buffer 1 size ~2400
number of storage characters in buffer 1=0
number of free spaces in buffer 1~2400

Buffer 3 starts at = 0x1391
Buffer 3 ends at ~x14BD
Buffer 3 size ~300
number of storage characters in buffer 3=0
number of free spaces in buffer 3~300

Buffer 4 starts at = 0x12C7
Buffer 4 ends at ~x132B
Buffer 4 size ~100
number of storage characters in buffer 4=0
number of free spaces in buffer 4~100
characters in buffer 0
stored chars=0

17°C
Haze
Search
ENG
IN
19:18
27-10-2023
```

For the optional challenges part, where the heap is created with 5600 bytes. Heap report after creating a buffer of 210 bytes.

```
COM11 - Tera Term VT
File Edit Setup Control Window Help
Buffer 1 starts at = 0x965
Buffer 1 ends at ~x12C5
Buffer 1 size ~2400
number of storage characters in buffer 1=0
number of free spaces in buffer 1~2400

Buffer 3 starts at = 0x1391
Buffer 3 ends at ~x14BD
Buffer 3 size ~300
number of storage characters in buffer 3=0
number of free spaces in buffer 3~300

Buffer 5 starts at = 0x14BF
Buffer 5 ends at ~x1591
Buffer 5 size ~210
number of storage characters in buffer 5=0
number of free spaces in buffer 5~210
characters in buffer 0
stored chars=0
total characters entered=3
heap report is done

OPTIONS
You can enter storage characters from '0' to 'Z' to store in buffer 0
Press + to create a new buffer of size between 20 and 400 bytes
Press - to delete a buffer.
Press ? to generate a heap report.
Press = to display current contents of buffer 0.
Press 0 to free all buffers and start program again.
enter the input

17°C
Haze
Search
ENG
IN
19:18
27-10-2023
```

For the optional challenges part, where the heap is created with 5600 bytes. Heap report after creating a buffer of 800 bytes.

```

COM11 - Tera Term VT
File Edit Setup Control Window Help
You can enter storage characters from 'A' to 'Z' to store in buffer 0
Press + to create a new buffer of size between 20 and 400 bytes
Press - to delete a buffer.
Press ? to generate a heap report.
Press = to display current contents of buffer 0.
Press 0 to free all buffers and start program again.

enter the input
+
enter buffer size between 20 AND 400 for the new buffer
300
entered input:300
memory allocation successful for buffer 3

OPTIONS
You can enter storage characters from 'A' to 'Z' to store in buffer 0
Press + to create a new buffer of size between 20 and 400 bytes
Press - to delete a buffer.
Press ? to generate a heap report.
Press = to display current contents of buffer 0.
Press 0 to free all buffers and start program again.

enter the input
-
enter the buffer number to be deleted
2
entered input:2
Freed buffer_2

OPTIONS
You can enter storage characters from 'A' to 'Z' to store in buffer 0
Press + to create a new buffer of size between 20 and 400 bytes
Press - to delete a buffer.
Press ? to generate a heap report.
Press = to display current contents of buffer 0.
Press 0 to free all buffers and start program again.

enter the input
+
enter buffer size between 20 AND 400 for the new buffer
800
entered input:800
memory allocation failed for buffer 4

OPTIONS
You can enter storage characters from 'A' to 'Z' to store in buffer 0
Press + to create a new buffer of size between 20 and 400 bytes
Press - to delete a buffer.
Press ? to generate a heap report.

```

Code snippet which I used to avoid button debouncing.

```

/**
 * @brief Handle the EXTI0 (External Interrupt 0) interrupt
 * @note This function is an interrupt handler.
 */
void EXTI0_IRQHandler(void) {
    if (EXTI->PR & EXTI_PR1_PR0) {
        EXTI->PR |= EXTI_PR1_PR0; // Clear pending bit for EXTI line 0 (PortA Pin 0)

        if (!buttonPressed) {
            TIM2->CR1 |= TIM_CR1_CEN; // Start Timer 2 for debouncing
            buttonPressed = 1; // Set button press state
        }
    }
}

```

## SIGNIFICANT LEARNINGS:

- I have learned how to use Paulmon2 commands to modify the data segment and navigate through the program segment.
- I have learned how to run a specific program by jumping to its location using Paulmon2 commands.
- I have learned how to write a User Interface for dynamic memory allocation of buffers in heap memory and perform various functions on it.
- I have learned how to implement PWM using a GPIO pin and change the LED intensity using PWM.
- I have learned about different PCA modes while implementing the supplementary and challenge elements.